

REMARKS

This paper is responsive to a non-final Office action dated October 20, 2003. Claims 1 – 29 were examined. Applicant respectfully traverses all rejections.

Rejections under 35 U.S.C. §103(a)

The Office Action has rejected claims 1 – 29 under 35 U.S.C. §103(a) as being unpatentable over John D. Valois' Lock-Free Linked Lists Using Compare-and-Swap © 1995 ("Valois") in view of U.S. Patent No. 5,765,175 granted to Bradford H. Needham and Ken A. Root ("Needham").

As a preliminary matter, it is important to note that design of concurrent software that operates correctly given possible interleaving of concurrently executed operations on shared objects (e.g., different threads concurrently operating on a shared object) is extremely complex. Indeed, the challenges presented in designing such software have been the subject of intense research interest over the years. One of the challenges includes implementing non-blocking linked-list operations with a concurrency characteristic of linearizability. Linearizability is an art-recognized characteristic that is desirable; however it is often not achieved in many real world systems. Neither of the two relied upon references discloses a linearizable implementation as claimed. For this reason alone, the rejections should be withdrawn. Moreover, it is well understood that even the slightest change to concurrent algorithms or data structure implementations can (and often does) destroy its correctness, let alone its concurrency behaviors, such as linearizability. As a result, one of ordinary skill in the art will recognize that it is, at best, inaccurate to 1) postulate a linearizable implementation of a first technique, and 2) identify a construct employed in a second technique (indeed, in the present case, a second technique that does not even contemplate concurrent operations) and presume that either concurrency or linearizability would be preserved if the identified construct from the second technique is applied to the first technique.

In short, the references relied upon do not disclose or suggest (alone or in combination) the claimed features, and furthermore, it is simply unsupportable to presume that a concurrency

behavior of an implementation disclosed in one of the cited references would survive importation of a logical deletion construct from the other.

Turning now to specifics of the claims, neither Valois nor Needham (standing alone or in combination) discloses or suggests: 1) “linearizable operations defined to implement semantics of at least insert and remove operations” as in Applicant’s claim 1 and similarly in Applicant’s other independent claims; and 2) mediation of concurrently executing linearizable operations “using a first synchronization primitive to encode a marked node indication signifying logical deletion of a corresponding one of the values from the group” as in claim 1, and similarly in Applicant’s other independent claims.

No Suggestion or Teaching of Linearizable Operations to Implement Insert and Remove Operations

Neither Valois nor Needham discloses linearizable operations as claimed. The Office Action simply assumes that the operations of Valois are linearizable, but Valois does not disclose or suggest linearizable operations, much less any technique whereby linearizable operations might be provided while using a logical deletion mechanism such as claimed. If a data structure is linearizable, then “the data structure behaves as if the operations on it requested by various processes are performed atomically in some sequential order and that such operations appear to take effect at some point between their invocation and response” (p.8 of the Specification). With Valois, it is possible for inserted cells to be lost if the dummy tail pointer lags behind and a process frees a removed cell. Since the inserted cells are lost, the inserted cells are not visible to subsequent operations. If the cells are lost and not observable by subsequent operations, the insertion does not seem to take effect between invocation and response. Atomicity and sequential ordering are violated, thus Valois’ operations are not linearizable.

Needham concerns a file system directory technique for write-once or erase-slowly media (e.g., flash media). Unlike Valois, Needham’s techniques do not even relate to concurrent operations on a shared object. Indeed, Needham never contemplates concurrency, much less linearizability of operations concurrently executed.

Accordingly, neither Valois nor Needham, standing alone or in combination, disclose or suggest:

linearizable operations defined to implement semantics of at least insert and remove operations on the group, wherein concurrent execution of the linearizable operations is mediated using a first synchronization primitive to encode a marked node indication signifying logical deletion of a corresponding one of the values from the group (claim 1); and

a first of the functional sequences defined to implement semantics of an insert operation on the group; and
 a second of the functional sequences defined to implement semantics of a remove operation on the group,
 wherein **instances of the functional sequences are linearizable** and concurrent execution thereof by plural processors of a multiprocessor is mediated using a synchronization primitive to encode a marked node indication signifying logical deletion of a corresponding one of the values from the group with separate physical excision of the corresponding node (claim 25).

None of the art of record discloses or suggests the above quoted claim language, and especially does not support the Office Action's characterization of Valois' operations as linearizable. Accordingly, the above quoted claims and dependents therefrom are allowable for at least the reasons given above.

No Suggestion or Teaching of Mediating Concurrently Executing Linearizable Operations by Using a Synchronization Primitive to Encode a Marked Node Indication Signifying Logical Deletion from A Linked-List

As previously stated, implementing non-blocking linked-list operations is complex even without implementing such operations as linearizable. The Office Action ignores this complexity and assumes that such complex software design can be achieved by extracting Needham's technique and, without explanation, concluding the obviousness of modifying Valois with the extracted technique. Needham utilizes a linked list of nodes, each of which includes a delete flag field, as a file directory (*see* Abstract). Needham uses the delete flag field to mark a

file for deletion without immediately modifying the file directory (col. 3, lines 4 – 24). Needham is completely void of relevant concepts such as concurrency and linearizability, yet the Office Action attempts to modify Valois to utilize the delete flag field of Needham with a simple assertion that such modification of Valois with Needham is obvious.

Turning to the obviousness rejections made by the Office, two errors are notable:

- 1) the references are not properly combinable to achieve that which the Office asserts in the combination
- 2) even if combined (albeit improperly), the references do not disclose or suggest all aspects of Applicant's claims

Proper combination of references requires not only a teaching or suggestion to combine specific aspects of one design or implementation with another, but also some expectation that the combination would operate correctly, e.g., without interfering (or destroying) correctness of the modified implementation. "If the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims *prima facie* obvious" (MPEP 2143.01). Where, as here, the Office attempts to import into concurrent software, a design feature implemented without regard to concurrency, the principle of operation of Valois, at a minimum, would change, and most likely would not operate properly (assuming that someone can even resolve the problem of how to actually modify Valois with Needham).

Merely adding a delete flag field to Valois does not achieve Applicant's claimed invention. In fact, without Applicant's disclosure, the manner of modifying Valois to utilize a delete flag field is unknown. It is not known how one would modify Valois to implement a marked node indication to signify logical deletion of a node, and the simple addition of a delete flag from Needham does not provide any guidance. Valois' Delete calls TryDelete, which swings pointers and maintains auxiliary cells, and then actually deletes the target cell with a call to Update. In addition, Valois operates on a linked-list of cells with a cursor construct. The references and the Office Action do not provide any guidance at least as to how Valois' operations would utilize a delete flag field, nor how the cells or cursor would be affected.

In fact, the Office's basis for modifying Valois with Needham ("because this would identify nodes in the list that need to be physically removed so that memory of the deleted nodes can be reclaimed") is contradictory to the operations of Valois. Valois reclaims memory within Update as identified by TryDelete, both of which are called from Delete (i.e., there is no need in Valois to identify cells for reclamation because Valois' delete operation includes memory reclamation). **Modifying Valois as suggested by the Office Action, which still does not achieve Applicant's claimed invention, would involve substantial changes to the operations implemented in Valois. The statement in the Office Action has no support in either Valois or Needham. There is no indication or explanation of how Needham's delete flag would be employed by Valois other than the conclusory statement in the Office Action.** "The level of skill in the art cannot be relied upon to provide the suggestion to combine references" (MPEP 2143.01). The Office Action has not established at least one of the three requirements for a *prima facie* case of obviousness. Moreover, the combination or modification of Valois with Needham still would not suggest or disclose Applicant's claimed invention.

Accordingly, neither Valois nor Needham, standing alone or in combination, disclose or suggest:

linearizable operations defined to implement semantics of at least
insert and remove operations on the group, **wherein concurrent
execution of the linearizable operations is mediated using a
first synchronization primitive to encode a marked node
indication signifying logical deletion of a corresponding one of
the values from the group (claim 1);**

...at least two functional sequences;
**the first functional sequence performing a logical deletion of the
value using a synchronization primitive to mark a corresponding
one of the nodes (claim 16);**

a first of the functional sequences defined to implement semantics of
an insert operation on the group; and
a second of the functional sequences defined to implement semantics of
a remove operation on the group,
wherein instances of the functional sequences are linearizable and
concurrent execution thereof by plural processors of a

multiprocessor is mediated using a synchronization primitive to encode a marked node indication signifying logical deletion of a corresponding one of the values from the group with separate physical excision of the corresponding node (claim 25); and

means for coordinating concurrent execution, by ones of the plural processors, of at least insert and remove operations on a group of zero or more values encoded in the one or more data stores, the coordinating employing a first synchronization primitive to encode an indication signifying logical deletion of a corresponding one of the values from the group and a second synchronization primitive to physically excise the node corresponding to the logically deleted value (claim 29).

None of the art of record discloses or suggests the above quoted claim language. Accordingly, the above quoted claims and dependents therefrom are allowable for at least the reasons given above.

Dependent Claims

The Office Action mistakenly states that Valois' Reclaim is independent of the Delete. However, Reclaim falls within the following chain of invocations: Delete→TryDelete→Release→Reclaim. Valois' reclamation of an excised cell is integrated with deletion of the cell, and not independent. Valois and Needham (standing alone or in combination) do not disclose or suggest "reclamation of storage associated with the excised node is **independent of the linearizable operations**" as in claim 4.

The Office Action also mistakenly assumes that Valois does not utilize reference count storage for coordination with garbage collection. In section 5.1, Valois identifies utilization of a reference counter to avoid the ABA problem. Valois' maintains the reference counter with SafeRead and Release. Valois and Needham (standing alone or in combination) do not disclose or suggest "the **linked-list of nodes is free of reference count storage for coordination** of garbage collection" as in claim 5. Also, Valois' traversal operations Next and First call update operations SafeRead and Release, which maintain reference counters for

garbage collection as already explained. Hence, Valois updates the garbage collection coordination store reference counter and does not disclose or suggest **“traversal of the concurrent shared object is without atomic update of a garbage collection coordination store”** as in claim 6, and **“means for traversing the encoded group without use of an atomic operation”** as in independent claim 29.

The Office Action also mistakenly describes Valois' deletion and traversal operations. Maintenance of the auxiliary cells in Valois' TryDelete causes Valois to update a linked-list numerous times: the greater the number of auxiliary cells, the greater the number of calls to Release and SafeRead. As previously stated, Valois updates a linked-list during traversal of the linked-list. Valois and Needham (standing alone or in combination) do not disclose or suggest **“successful completion of a deletion from the group requires, at most, two atomic updates of the concurrent shared object...and wherein mere traversal of the concurrent shared object is without atomic update of the concurrent shared object”** as in claim 7.

With regard to claim 14, Valois and Needham (standing alone or in combination) do not disclose or suggest **“the marked node indication includes a distinguishing bit value in an otherwise unused portion of a next node pointer of the logically deleted node.”** The Office Action refers to the section of Needham that discloses its delete flag field, but nothing in Needham discloses the above quoted claim language.

With regard to claim 15, Valois and Needham (standing alone or in combination) do not disclose or suggest **“the marked node indication includes a distinguishing additional level of indirection between the next node pointer of the logically deleted node and a respective other one of the nodes.”** The Office Action refers to Valois copying the pre_cell field of the cursor into a target cell's back_link during TryDelete to allow traversal back to a cell that has not been deleted. Valois does not employ marked node indication for logical deletion of a node, and the back_link field is not an additional level of indirection between the next cell pointer of a target cell and another cell. The back_link directly refers to a preceding normal cell and is separate from the next_cell pointer.

Neither Valois nor Needham, standing alone or in combination, discloses or suggests Applicant's claimed invention. For at least the reasons stated above, Applicant respectfully

submits that Applicant's independent claims 1, 16, 25, and 29 are allowable, and a Notice of Allowance to that effect is respectfully requested. In addition, all of the dependent claims are dependent on corresponding ones of the above allowable independent claims. Applicant respectfully submits that all of the dependent claims are allowable for at least the reasons discussed above.

Conclusion

In summary, claims 1-29 are in the case. All claims are believed to be allowable over the art of record, and a Notice of Allowance to that effect is respectfully solicited. Nonetheless, if any issues remain that could be more efficiently handled by telephone, the Examiner is requested to call the undersigned at the number listed below.

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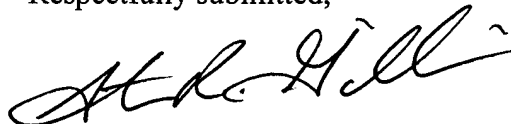
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Respectfully submitted,



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